

Loads and Dynamics Harmonization Working Group

Disposition of Comments

AWM-98-12 A

Date: 5/19/00

Document: Notice 99-08 "Revised Landing Gear Shock Absorption Test Requirements"

Published: Federal Register, Vol 64, No 117, June 18, 1999

Date comment period closed: October 18, 1999

General assessment of comments:

There were 6 commenters from aviation manufacturers and foreign airworthiness authorities. Although one commenter objected to the proposed rule, most of the commenters supported the proposed changes. Several of the commenters provided suggestions for clarity, consistency and organization. Because of the substantive nature of some of the comments, the FAA requested the ARAC Loads and Dynamics Working Group by letter dated February 8, 2000 to consider the comments and provide recommendations for the disposition of the comments along with any recommendations for changes to the proposal. Comments are summarized as follows along with recommended disposition text for the final rule.

1) Object to change in basic purpose of the shock absorption tests

One commenter objected to the proposed change in the basic purpose of the shock absorption test from the validation of the load factors to the validation of the dynamic characteristics of the landing gear. The commenter believes that the new proposal has the potential for requiring a significant volume of re-calculation for refinement of load values and this would be neither productive nor cost effective. Furthermore, the commenter believes that this approach would not fit well in the timeline between design concept and the development of the first prototype and so would bring the potential for discovering a different answer for the completed product late in the design process. Finally, the commenter believes the existing regulations are sufficient. The FAA agrees that validation of dynamic characteristics by test always brings a risk if the assumptions made in the prediction of these characteristics are not sufficiently accurate or conservative. However, the process of prediction, design, and validation are normal, and expected, in the development of aircraft and the risks can be minimized by the use of conservative assumptions. Furthermore, the FAA does not agree that the existing shock absorption test requirements are sufficient. The development of airplane loads for dynamic landing conditions requires a valid analytical model of the landing gear which includes a valid representation of the energy absorbing characteristics of the gear. The dynamic landing requirement has existed in CFR 14 for a number of years but the validation shock absorption test requirement has remained outdated, since it requires only the validation of a simple static landing load factor which may not even be used in design of the airplane. Because of the existing dynamic landing requirement, it has become a standard practice

to develop the design loads for the airplane structure based on a mathematical model of the airplane and landing gear and to validate the assumed gear characteristics by shock absorption tests. Therefore, the requirement is being updated to be consistent with the related design landing load requirements and also to be consistent with standard practice.

2) Recommend consistent terminology.

One commenter pointed out that the terminology used in the proposed 25.723(a)(1) for design weight conditions were inconsistent with those used in § 25.473 "Landing load conditions and assumptions", which are the same as those used in the proposed AC 25.723-1. The FAA agrees, and the language in the new paragraph 25.723(a)(1) has been changed to use the same terms "design landing weight" and "design takeoff weight" as currently used in § 25.473.

3) Objects to implication that tests would be required for unsymmetrical landing conditions.

One commenter was concerned that the proposed location of the requirement for shock absorption tests in 25.473(d) implies that the individual tests would be required for each of the landing conditions and configurations specified in § 25.473 including unsymmetrical conditions. The FAA does not agree since the specific landing conditions are referenced in paragraph 25.473(a) while the requirement related to validating landing gear dynamic characteristics, potentially of use in some or all conditions, is set forth in a separate paragraph 25.473(d). Validation is intended to mean that the adequacy of the dynamic characteristics would be confirmed by shock absorption tests to whatever extent necessary to provide confidence in the analysis of the specified landing conditions.

4) Recommend that the specific "dynamic characteristics" be listed in the rule.

The same commenter suggested that the terms, "dynamic characteristics", are ambiguous and that the rule should completely define dynamic characteristics and specify which dynamic characteristics must be validated by tests. The FAA agrees that these terms are general. However, the FAA does not agree that an exhaustive list of dynamic characteristics or shock absorption characteristics can be provided in the rule. The landing gear dynamic characteristics depend on the parameters chosen by the applicant for use in the analysis. The analysis must represent the full energy absorbing characteristics of the landing gear and it would be impossible to provide an exhaustive list of characteristics that would apply to all designs. Typically the manufacturer will validate the dynamic characteristics used in the analysis in a gross fashion by using the analytical mathematical model to predict the shock absorption response time histories in the test for a range of test conditions. In response to this comment, changes have been made to the proposed advisory material to identify some of the energy absorption components and characteristics that are usually of significance and the extent that they could be changed or revised without additional testing.

5) Object to elimination of the reserve energy shock absorption tests 25.723(b).

One commenter was concerned that the elimination of 25.723(b) meant that the reserve energy shock absorption tests would no longer be required. Removal of 25.723(b) was not a proposal of notice 99-08. The commenter failed to recognize that the paragraph is represented in the notice as a set of asterisks at the end of 25.723(a) signifying that the remaining paragraphs of § 25.723 would remain unchanged. However, consideration of the commenters concern brought to light the fact that the allowance provided in 25.723(a) for using analysis in lieu of tests, would not necessarily apply to the reserve energy drop test of paragraph 25.723(b). In order to correct this oversight, paragraph 25.723(b) is clarified, and the allowance in the proposed paragraph 25.723(a) is now set forth in a separate paragraph 25.723(c) and made applicable to both paragraphs 25.723(a) and (b).

6) Object to eliminating of the reserve energy free drop tests (25.725 and 25.727).

One commenter was concerned that the removal of the free drop test requirements in 25.725 and 25.727 from the rules meant that these tests would no longer be required and that this could result in a reduction in the degree of safety. These specific types of tests, known as free drop tests, have never been required. They have always been a means of compliance to the general requirement to conduct shock absorption tests. This general requirement for conducting shock absorption tests remains in the revised § 25.723. The free drop test criteria are provided for the manufacturer that chooses to use this particular method of performing the required shock absorption tests. In the free drop test, the manufacturer may represent the airplane lift by using a reduced effective weight for the test. However many manufacturers represent the lifting force directly in a drop test or perform other types of shock absorption tests. The criteria for establishing the effective drop weight is applicable to only this one means of compliance and more appropriately presented in an Advisory Circular (AC). To this end AC 25.723-1 "Shock absorption tests" has been made available to provide this means of compliance.

Two commenters were concerned that the removal of the free drop test criteria from the regulation would result in the loss of the current method for establishing the effective mass over the nose gear for the free drop test. As stated above, this information is not being lost but is being moved to an Advisory Circular as acceptable means of compliance.

Conclusions:

Except for the minor editorial and organizational changes mentioned above, the amendment and advisory circular are acceptable as proposed.

Recommended revised proposal:

§ 25.473 Landing load conditions and assumptions.

* * * * *

(d) The landing gear dynamic characteristics must be validated by tests as defined in § 25.723(a).

* * * * *

§ 25.723 Shock absorption tests.

(a) The analytical representation of the landing gear dynamic characteristics that is used in determining the landing loads must be validated by shock absorption tests. A range of tests must be conducted to ensure that the analytical representation is valid for the design conditions specified in 25.473 ~~The landing gear dynamic characteristics used for design must be validated by energy absorption tests. The dynamic characteristics must be valid for all design conditions.~~

(1) The configurations subjected to energy absorption tests at limit design conditions must include at least the design landing weight or the design takeoff weight, whichever produces the greater value of landing impact energy.

(2) The test attitude of the landing gear unit and the application of appropriate drag loads during the test must simulate the airplane landing conditions in a manner consistent with the development of rational or conservative limit loads.

~~(3) In lieu of the tests prescribed in this section, changes in previously approved design weights and minor changes in design may be substantiated by analyses based on previous tests conducted on the same basic landing gear system that has similar energy absorption characteristics.~~

(b) The landing gear may not fail in a test, demonstrating its reserve energy absorption capacity, simulating a descent velocity of 12 f.p.s. in a level attitude at design landing weight, assuming airplane lift not greater than the airplane weight acting during the landing impact.

(c) In lieu of the tests prescribed in this section, changes in previously approved design weights and minor changes in design may be substantiated by analyses based on previous tests conducted on the same basic landing gear system that has similar energy absorption characteristics.

§ 25.725 [Removed and Reserved]

§ 25.727 [Removed and Reserved]

Draft Advisory Circular 25.723-1 (attached)

Advisory Circular

U.S. Department
of Transportation
**Federal Aviation
Administration**

SHOCK ABSORPTION TESTS

Date:

Initiated by: ANM-110

AC No. 25.723-1

Change:

1. **PURPOSE.** This advisory circular (AC) sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of part 25 of the Federal Aviation Regulations (FAR) related to the use of landing gear shock absorption tests and analyses to determine landing loads for transport category airplanes.

2. **RELATED FAR SECTIONS.** Part 25, Section 25.723 "Shock absorption tests" and Section 25.473 "Ground load conditions and assumptions."

3. **BACKGROUND.** The requirement concerning energy absorption tests for landing gear units existed in the earliest versions of the Civil Aeronautics Regulations (CAR) Part 04. Questions concerning the need for the tests and the use of analyses in lieu of tests have existed since the CAR 04 and have resulted in revisions to the successor regulations CAR 4b, which replaced CAR 04, and later in the Federal Aviation Regulation (FAR), Part 25, which replaced CAR 4b.

a. Section 04.34 of CAR 04 (July 1944) allowed analyses in lieu of tests when the landing gear structure conformed to conventional types for which reliable analytical methods were available. With the advancing complexity of landing gear units, the rule was revised (CAR 4b, Section 4b.332) to require energy absorption tests to determine the landing load factors both at design landing weight and design takeoff weight. Although this rule did not specifically provide for analyses in lieu of tests, it was common practice to allow later changes in design weights to be substantiated by analytical methods which were validated by the results of the earlier tests.

b. Recognizing the need to provide for subsequent growth in the design weights, the Federal Aviation Administration (FAA) revised § 25.723 (Amendment 25-46) to clarify that analyses could be used to substantiate changes in the design takeoff and design landing weights provided these analyses were validated by the results of tests conducted on identical landing gear units.

c. Although the rule referred to tests on the "identical" landing gear units, subsequent changes in the design weights often are accompanied by minor changes in other parameters affecting the landing gear energy absorption characteristics. These included changes in the shock absorber orifice size and metering pins shape, and changes in tire inflation limits. The FAA revised § 25.723 (Amendment 25-72) to further clarify that the analyses could be based on tests performed on the same basic landing gear system with similar energy absorption characteristics.

d. In the mean time, other requirements have resulted in changes in the way the test and analytical data are used. The shock absorption tests are no longer used just to determine the landing load factors. It is now necessary to account for dynamic landing conditions in which the dynamic characteristics of the airplane and landing gear acting together are used to determine the landing loads. As a practical matter, the analytical modeling of the landing gear dynamic characteristics are indispensable in determining that landing loads and the shock absorption tests are needed in order to validate the mathematical modeling of the landing gear units.

4. SHOCK ABSORPTION TESTS.

a. Validation of the landing gear characteristics. Shock absorption tests are necessary to validate the analytical representation of the dynamic characteristics of the landing gear unit that will be used to determine the landing loads. A range of tests should be conducted to ensure that the analytical model is valid for all for reasonable extrapolations to other design conditions, and configurations expected in service. In addition, consideration should be given to ensuring that the range of test configurations are sufficient for justifying the use of the analytical model for foreseeable future growth versions of the airplane.

b. Recommended test conditions for new landing gear units. The design takeoff weight and the design landing weight conditions should both be included as configurations subjected to energy absorption tests. However, in cases where the manufacturer has supporting data from previous experience in validating the analytical model using landing gear units of similar design concept, it may be sufficient to conduct a single shock absorption test tests of the new landing gear at only for the condition associated with maximum energy. The similar landing gear used to provide the additional supporting data may be from another model aircraft but the landing gear unit should be of approximately the same size with similar components.

c. Changes to type designs. Subsequent changes to the landing conditions or to the landing gear units may be substantiated by analyses based on tests of the same basic landing gear unit with similar dynamic characteristics, provided the design concept has not changed and the results of the previous energy absorption tests are sufficient to realistically validate the analytical results for the design changes. For example, the following changes may be acceptable without further tests: Section 25.723(c) allows changes in previously approved design weights and minor changes in design to be substantiated by analyses based on tests of the same basic landing gear unit with similar energy absorption characteristics.

A landing gear unit would be considered to be of "the same basic landing gear system" when the design concept has not been changed. "Similar energy absorption characteristics" means that the changes to the landing gear unit, either taken individually or as a whole, would not have a significant effect on the validation of the analytical results for the modified airplane. Changes that may be acceptable without further energy absorption tests include minor changes and adjustments incorporated in the landing gear unit to maintain similar energy absorption characteristics with changes in design weight and landing speeds.

(1) Airplane sprung mass (effective weight) variations, including extrapolation from maximum landing weight to maximum take-off weight conditions.

~~—— (2) Changes in shock absorber characteristics including pre-load, compression ratio, orifice sizes.~~

~~—— (3) Changes in tire characteristics.~~

~~—— (4) Changes in unsprung mass (e.g. brakes).~~

~~—— (5) Local strengthening or minor sizing changes to the landing gear.~~

For example, the following changes may be acceptable without further tests:

- Minor changes in shock absorber details including pre-load, compression ratio, orifice sizes, metering pin profiles.
- Minor changes in tire characteristics.
- Minor changes in unsprung mass (e.g. brakes).
- Local strengthening or minor sizing changes to the landing gear.

To allow justification by analysis for the reserve energy requirement, the principal components of the landing gear should not be exhausted of energy absorbing capacity neither the shock strut nor the tires should bottom during the reserve energy analysis or the tests upon which the analysis is correlated.

5. LIMIT FREE DROP TESTS.

(a) Compliance with § 25.723(a) may be shown by free drop tests, provided they are made on the complete airplane, or on units consisting of a wheel, tire, and shock absorber, in their proper positions, from free drop heights not less than—

(1) 18.7 inches for the design landing weight conditions; and

(2) 6.7 inches for the design takeoff weight conditions.

(b) If airplane lift is simulated by air cylinders or by other mechanical means, the weight used for the drop must be equal to W . If the effect of airplane lift is represented in free drop tests by a reduced weight, the landing gear must be dropped with an effective weight equal to

$$W_e = W \left[\frac{h + (1 - L)d}{h + d} \right]$$

where—

W_e = the effective weight to be used in the drop test (lb);

h = specified free drop height (inches);

d = deflection under impact of the tire (at the approved inflation pressure) plus the vertical component of the axle travel relative to the drop weight (inches);

W = W_M for main gear units (lb), equal to the static weight on that unit with the airplane in the level attitude (with the nose wheel clear in the case of nose wheel type airplanes);

W = W_T for tail gear units (lb), equal to the static weight on the tail unit with the airplane in the tail-down attitude;

W = W_N for nose wheel units (lb), equal to the vertical component of the static reaction that would exist at the nose wheel, assuming that the mass of the airplane acts at the center of gravity and exerts a force of 1.0 g downward and 0.25 g forward; and

L = ratio of the assumed airplane lift to the airplane weight, but not more than 1.0.

(c) The drop test attitude of the landing gear unit and the application of appropriate drag loads during the test must simulate the airplane landing conditions in a manner consistent with the development of a rational or conservative limit loads.

(d) The value of d used in the computation of W_e in paragraph (b) of this section may not exceed the value actually obtained in the drop test.

6. RESERVE ENERGY FREE DROP TESTS.

(a) Compliance with the reserve energy absorption condition specified in § 25.723(b) may be shown by free drop tests provided the drop height is not less than 27 inches.

(b) If airplane lift is simulated by air cylinders or by other mechanical means, the weight used for the drop must be equal to W . If the effect of airplane lift is represented in free drop tests by an equivalent reduced weight, the landing gear must be dropped with an effective weight.

$$W_e = \frac{Wh}{h+d}$$

where the symbols and other details are the same as in paragraph 5 above.

f:\home\jhaynes\arac\ac25723.doc

TRANSFERRED TO:

f:\home\jthor\rules\shock-ac.doc on 10-18-95

revised 10-18-95 (JT editorial changes)

revised 10-30-95 (NS edits)

revised 3/11/96 (ACO comments)

revised 2/8/00 (LCH – L&DHWG reponse to public comments)

revised 4/11/00 (J. Haynes to reflect Boeing Comments) See changes in blue color.

revised 5/2/00 (LCH to remove Boeing suggested paragraph 6.(c))

U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

SHOCK ABSORPTION TESTS

Date:
Initiated by: ANM-110

AC No. 25.723-1
Change:

1. **PURPOSE.** This advisory circular (AC) sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of part 25 of the Federal Aviation Regulations (FAR) related to the use of landing gear shock absorption tests and analyses to determine landing loads for transport category airplanes.
2. **RELATED FAR SECTIONS.** Part 25, Section 25.723 "Shock absorption tests" and Section 25.473 "Ground load conditions and assumptions."
3. **BACKGROUND.** The requirement concerning energy absorption tests for landing gear units existed in the earliest versions of the Civil Aeronautics Regulations (CAR) Part 04. Questions concerning the need for the tests and the use of analyses in lieu of tests have existed since the CAR 04 and have resulted in revisions to the successor regulations CAR 4b, which replaced CAR 04, and later in the Federal Aviation Regulation (FAR), Part 25, which replaced CAR 4b.
 - a. Section 04.34 of CAR 04 (July 1944) allowed analyses in lieu of tests when the landing gear structure conformed to conventional types for which reliable analytical methods were available. With the advancing complexity of landing gear units, the rule was revised (CAR 4b, Section 4b.332) to require energy absorption tests to determine the landing load factors both at design landing weight and design takeoff weight. Although this rule did not specifically provide for analyses in lieu of tests, it was common practice to allow later changes in design weights to be substantiated by analytical methods which were validated by the results of the earlier tests.
 - b. Recognizing the need to provide for subsequent growth in the design weights, the Federal Aviation Administration (FAA) revised § 25.723 (Amendment 25-46) to clarify that analyses could be used to substantiate changes in the design takeoff and design landing weights provided these analyses were validated by the results of tests conducted on identical landing gear units.
 - c. Although the rule referred to tests on the "identical" landing gear units, subsequent changes in the design weights often are accompanied by minor changes in other parameters affecting the landing gear energy absorption characteristics. These included changes in the shock absorber orifice size and metering pins shape, and changes in tire inflation limits. The FAA revised § 25.723 (Amendment 25-72) to further clarify that the analyses could be based on tests performed on the same basic landing gear system with similar energy absorption characteristics.